

APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: **DEPOSITING AN OXIDE**

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Depositing An Oxide

Background

This invention relates generally to the fabrication of semiconductor devices and specifically to deposition
5 techniques.

Incompatibilities between the metal and oxide layers in Metal-Oxide-Semiconductor or Metal-Oxide-Silicon (MOS) structures may arise in those MOS structures having a dielectric with a high dielectric constant (high-k) and a
10 polysilicon or metal gate electrode. For example, a MOS structure having a high-k dielectric and a polysilicon gate electrode may form nodules that may short the dielectric. Further, the nodules may pin the Fermi level in the polysilicon gate. Alternately, a MOS structure having a
15 high-k dielectric and a metal gate electrode may experience an undesirable shift in the gate metal work function. A shift in work function may lead to unstable threshold voltages thereby affecting device performance. As such, another oxide such as a buffer oxide may be deposited
20 between the high-k dielectric and gate material.

Buffer oxides may be deposited on a substrate via chemical vapor deposition (CVD) processing techniques. For example, deposition precursors may first be deposited on the substrate and then oxidized. However, some of the
25 precursors used in the CVD of buffer oxide may be highly

toxic and may spontaneously ignite and burn on contact with air. Thus, the CVD buffer oxide precursors pose a significant risk to those working in the semiconductor industry. Further, unconsumed CVD process gases and
5 deposition products may be as toxic as the starting materials. Thus, there is an additional hazard to the environment at large as a result of CVD of buffer oxide.

Accordingly, there continues to be a need for deposition techniques that are both environmentally and
10 user friendly.

Brief Description of the Drawings

Figure 1 is a cross sectional view of a gate stack of a MOS structure according to some embodiments of the present invention;

15 Figure 2 is a cross sectional view of the gate stack of Figure 1 during device fabrication;

Figure 3 is a flow chart for the preparation of an oxide deposition solution according to some embodiments of the present invention;

20 Figure 4 is a flow chart for the deposition of oxide on the gate stack of Figure 2 according to some embodiments; and

Figure 5 is a cross sectional view of the gate stack of Figure 2 after soaking in the oxide deposition solution
25 according to some embodiments of the present invention.

Detailed Description

Referring to Figure 1, according to some embodiments of the present invention, structure 10 such as a MOS structure as one example, may include a substrate 12, a dielectric 14, a buffer oxide 16 and a gate electrode 18. The substrate 12 may be any semiconducting material such as silicon or gallium arsenide as a few examples. Further, the dielectric 14 may be an oxide such as silicon dioxide (SiO_2), hafnium oxide (HfO_2) or zirconia (ZrO_2) as a few examples. Generally, hafnium oxide and zirconia are considered high-k dielectrics because they have high electrical permittivity. The dielectric 14 may be very thin, for example, 20 angstroms or less, although embodiments are not limited in this respect. The gate electrode 18 may be any suitable gate material such as a metal or polysilicon.

The buffer oxide 16 may be any oxide to buffer undesirable interactions between the dielectric 14 and the gate material 18. For example, the buffer oxide 16 may have a lower dielectric constant than the dielectric 14. As such, the buffer oxide 16 may form a more stable interface with a subsequently deposited gate material 18 than the dielectric 14. Further, the buffer oxide 16 may react with the dielectric 14 to remove any preexisting oxygen deficiencies or impurities and/or to passivate the dielectric 14 surface. Chemically, the buffer oxide 16 may be relatively stable, which buffers, or lessens the

reactivity between the dielectric 14 and the gate electrode 18. As such, adverse interactions between the dielectric 14 and gate 18 may be attenuated if not eliminated.

Nevertheless, according to certain embodiments of the present invention, the oxide 16 is ultra-thin (although embodiments are not limited to ultra-thin buffer oxide 16). In this way, overall gate stack capacitance may not be compromised.

As described herein, the buffer oxide 16 is aluminum oxide (Al_2O_3) and the dielectric 14 is hafnium oxide, although embodiments are not so restricted. Generally, aluminum oxide is relatively stable and has a lower dielectric constant than hafnium oxide. As such, aluminum oxide may form a more stable interface with a subsequently deposited gate 18 material.

Referring to Figure 2, during device fabrication the substrate 12 may be silicon having hafnium oxide 14 deposited thereon. The hafnium oxide 14 may be deposited on the substrate 12 by any conventional means such as sputter deposition, CVD or high-density plasma CVD as a few examples. Thereafter, the substrate 12 may be immersed in an oxide deposition solution according to embodiments of the present invention.

Referring to Figure 3, according to embodiments of the present invention, buffer oxide 16 may be deposited on a dielectric 14 via surface reactions while the substrate 12 is immersed in a "wet" oxide deposition or salt solution.

For example, to deposit aluminum oxide 16 on the hafnium oxide 14, a salt such as an aluminum salt may be dissolved in a solvent, as shown in box 20. In some embodiments the aluminum salt may be aluminum chloride or aluminum nitrate
5 that is dissolved in deionized water.

As shown in box 22, the pH of the oxide deposition solution or salt solution may be adjusted in some embodiments. For example, a base such as ammonia hydroxide or an acid such as hydrochloric acid may be added to the
10 salt solution. In some embodiments of the present invention, the pH modifying substance may be added as process demands require such as to remove potential contaminants. Further, the pH modifying substance may be utilized to dissolve any aluminum hydroxide precipitates or
15 hydrate aluminum ions.

Referring to Figure 4, after the oxide deposition solution has been prepared, and when called for pH adjusted, the substrate 12 may be dipped in the solution, as shown in block 24. The substrate 12 may be soaked for
20 about a few seconds to about an hour or more, although embodiments of the invention are not limited in this respect. While soaking in the salt solution, reactants in the solution and the top surface of the dielectric 14 may react to deposit the oxide 16 on the dielectric 14, as
25 shown in block 26. For example, aluminum hydroxide $\text{Al}(\text{OH})_3$ or hydrated aluminum ions may react with the top surface of the hafnium oxide 14 to form aluminum oxide 16. After

being immersed for a desired period of time, the substrate 12 may be removed from the salt solution and rinsed for example with deionized water, as shown block 28.

5 The thickness of the buffer oxide 16 deposited during substrate 12 soaking may be controlled. For example, the thickness of the aluminum oxide 16 deposited on the hafnium oxide 14 may be regulated by adjusting the concentration of aluminum salt dissolved in solvent and/or the time the substrate 12 is allowed to soak in the salt solution. That
10 is, in some embodiments of the present invention, the concentration of aluminum available for deposition may be about few parts per million (ppm) to about 1 percent or 1 mole. Accordingly, the surface concentration of aluminum oxide 16 may be modulated to range from about a few ppm or
15 less than a complete layer to one or more atomic layers.

Referring to Figure 5, as a result of exposure to the oxide deposition solution, the oxide 16 may be deposited on the dielectric 14. For example, a desired thickness of aluminum oxide 16 may be deposited on hafnium oxide 14.
20 Thereafter, a gate material 18 may be deposited on the oxide 16, as shown in Figure 1.

While the present invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and
25 variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.